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Identifying Tank Gunnery Skill Requirements on the Institutional Conduct-of-Fire Trainer (I-COFT)

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The U.S. Army Armor School (USAARMS), as directed by the Commander, Training and Doctrine Command (TRADOC), is developing a device-based training strategy. A primary goal of the strategy is to specify an optimal mix of field and simulation-based tactical and gunnery training. In support of the evolving strategy, this research developed and validated a set of analytical methods for identifying the underlying skill requirements of the tank gunner in armor gunnery tasks. The methods were tried by identifying the particular skills that are trained by the Institutional Conduct-of-Fire Trainer (I-COFT). To validate the skill assessment methods, an I-COFT tank gunnery test was administered to 18 soldiers enrolled in the initial-entry Excellence in Armor (EIA) program before and after 14 hours of EIA I-COFT training. The I-COFT test was also administered to 10 Noncommissioned Officer (NCO) gunnery instructors. A series of analyses compared changes in performance caused by training and differences between the EIA soldiers and NCOs. Skill development and error analysis methods were also developed, the results of which showed relative rates of skill development.

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The results showed that the skills needed to accurately hit stationary targets developed very quickly, as no differences were found between NCOs and EIA soldiers at the end of training. In contrast, the skills required for speed on both stationary and moving targets continued to develop across the full range of skill levels. The error analyses revealed that stationary target misses were mostly due to aiming too high or too low and that moving target misses were due to poor tracking. NCO tracking errors were largely the result of tracking too fast. Taken together, the analyses showed that tracking skills primarily accounted for speed and accuracy on both stationary and moving targets. Plans are underway to examine the generalizability of the skill assessment methods with other Armor training devices, including the Guard Unit Armory Device Full-Crew Interactive Simulation Training (GUARD FIST) and the Precision-Range Integrated Maneuver Exercise (PRIME).

Research Report 1583

Identifying Tank Gunnery Skill Requirements on the Institutional Conduct-of-Fire Trainer (I-COFT)

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Human Performance Effectiveness and Simulation

FOREWORD

Given recent world events, the need for efficient and cost-effective combat skills training is as great as ever. The U.S. Army is seeking ways to optimize training readiness of its close combat units through the calculated integration of training simulation technology. The research reported here supports this goal by developing and validating analytical methods to identify the combat gunnery skills that are trained by the high-fidelity Institutional Conduct-of-Fire Trainer (I-COFT) and, in extension, by determining how the training can be enhanced. The research was conducted under a Memorandum of Agreement with the Deputy Chief of Staff Training (DCST), U.S. Army Training and Doctrine Command (TRADOC), the Program Manager-Training Devices (PM-TRADE), U.S. Army Materiel Command, and the U.S. Army Armor Center entitled "The Effects of Simulators and Other Resources on Training Readiness."

The research was performed by the Fort Knox Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI). The research program is designed to support the development of an evolving field and simulation-based devices training strategy, a major goal of which is to specify an optimal mix of tactical and gunnery training. As a prerequisite of the train-ing strategy, this research identifies the underlying skill requirements of the tank gunner. The results show skill development profiles of soldiers enrolled in the Excellence in Armor (EIA) program relative to profiles of highly trained Noncommissioned Officers. The results of the research were briefed to the Director, Weapons Department, U.S. Army Armor School and were provided to the PM-TRADE Close Combat Training Systems.

EDGAR M. JOHNSON
Technical Director

IDENTIFYING TANK GUNNERY SKILL REQUIREMENTS ON THE INSTITUTIONAL CONDUCT-OF-FIRE TRAINER (I-COFT)

EXECUTIVE SUMMARY

Requirement:

The research was conducted to develop and validate a set of analytical methods for identifying the underlying skill requirements of the tank gunner in armor gunnery tasks. The methods were to be tried by using them to identify the particular skills that are trained by the I-COFT.

Procedure:

A set of analytical methods was developed to quantify changes in tank gunnery speed and accuracy, relative rates of skill development, and tank gunnery error patterns. To validate the methods, an I-COFT tank gunnery test was administered twice to 18 soldiers enrolled in the initial-entry Excellence in Armor (EIA) program, both before and after 14 hours of EIA I-COFT training. The I-COFT test was also administered to ten Noncommissioned Officer (NCO) gunnery instructors in the U.S. Army Armor School. The skill assessment methods were used to compare changes in performance that resulted from the 14 hours training and differences in tank gunnery between the EIA soldiers and the NCOs.

Findings:

The analytical methods were effective for quantifying changes in performance and for identifying performance profile differences between novice and expert performers. The results show that the skills needed to accurately hit stationary targets develop quickly—no differences in accuracy were found between the NCOs and the EIA soldiers on the moving targets. In contrast, the skills required for speed on both stationary and moving targets continued to develop across the entire range of skill levels. The error analyses revealed that stationary target misses were mostly due to aiming too high or too low and that moving target misses were due to poor tracking. NCO tracking errors largely resulted from tracking too fast.

The error analysis also showed that by the end of the 14 hours of EIA training, erratic tracking had largely disappeared. That the speed and accuracy of the EIA soldiers were sometimes equivalent to the NCOs does not imply that the EIA soldiers were as good as gunners as the NCOs. Being a good gunner requires a number of skills and knowledges other than being able to shoot the main gun in a normal operational mode, for example, crew-level maintenance. Taken together, the various analyses showed that tracking skills

primarily accounted for speed and accuracy on both stationary and moving targets.

Utilization of Findings:

The results have been given to the U.S. Army Armor School to help refine the Armor device-based training strategy. A primary goal of the strategy is to specify an optimal mix of simulation-based and field tactical and gunnery training. The validated analytical methods can also be used to identify skills trained by other devices and field training. Plans are underway to determine whether skill assessment methods can be generalized to other Armor training devices, including the Guard Unit Armory Device Full-Crew Interactive Simulation Training (GUARD FIST) and the Precision-Range Maneuver Exercise (PRIME).

IDENTIFYING TANK GUNNERY SKILL REQUIREMENTS ON THE INSTITUTIONAL CONDUCT-OF-FIRE TRAINER (I-COFT)

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IDENTIFYING TANK GUNNERY SKILL REQUIREMENTS ON THE INSTITUTIONAL CONDUCT-OF-FIRE TRAINER (I-COFT)

Introduction

Tank gunnery training has always been restricted by the range and lethality of tank ammunition. Given that tank rounds can travel in excess of a mile a second, safety constraints require that live-fire training be highly structured and controlled. As a result, live-fire tank gunnery training primarily consists of shooting pop-up plywood panels on bowling alley-like ranges. By contrast, combat is uncontrolled and chaotic. Targets appear in all directions and shoot back with comparable lethality. Friendly vehicles are intermingled among enemy targets and helicopters fly evasive maneuvers at 150 mph. Further, tankers are forced to fight after sustaining equipment damages by employing degraded mode operations. Until recently it has been impossible to train armor combat skills under these critical, realistic conditions.

Training simulators, such as the Institutional Conduct-of-Fire Trainer (I-COFT) and the Simulation Networking (SIMNET) system, are now being used to fill the void by training combat skills under conditions that were previously impossible to safely represent. These include realistic 360° air and ground target arrays with shoot-back capabilities and the safe training of degraded operational mode procedures. Simulation-based training can also provide repeated practice on varying scenarios and automated performance feedback capabilities. While the potential for simulation-based training is great, determining the types and amount of simulation-based training and how to best integrate the device-based training with field training remains largely unresolved. Clearly there is a dearth of empirical data that link amount and type of simulation-based training to skill development and field performance.

The U.S. Army Armor School (USAARMS), as directed by the Commander, TRADOC, has developed a training device macrostrategy that integrates the various devices into the overall Armor device-based training strategy (USAARMS, 1990a). A primary goal of the strategy is to specify an optimal mix of simulation-based and field tactical and gunnery training. The strategy is evolving in that new devices are being developed and training support resources are changing. USAARMS (1990b), for example, describes 14 armor training devices under development that are designed to complement the 11 training systems currently fielded.

A training strategy is basically a method for structuring instruction such that learning is enhanced and/or that training costs are reduced. A comprehensive armor training strategy is necessarily complex as it must address the training of individual, crew, and collective tasks in both the unit and the schoolhouse and for both active and reserve units. In addition, the training strategy must separately consider the requirements of skill acquisition and skill sustainment. The scope of a comprehensive Armor gunnery training strategy is demonstrated by Morrison and Holding (1990). Beginning with a set of training objectives, they discuss four key functions central to the development of the training strategy. The four functions are (a) to organize training objectives into units of instruction, (b) to sequence training both within and between units of instruction, (c) to select the appropriate medium or device for each unit of instruction, and (d) to allocate training time to each unit and/or device combination.

Considering the hundreds of individual and collective armor tasks and the number of simulation-based and field training methods available, an outright "optimal" training strategy is unlikely. Optimal refers here to maximum readiness at a minimum cost. On the other hand, there is considerable room for improvement. Currently, the increasing reliance on simulation-based training is largely being driven by the escalating costs of field and live-fire training. While this may be a fiscal necessity, the armor training strategy can continue to improve by better matching new training technology capabilities to specific skill requirements of combat proficiency. One persisting problem is that there is a gap in our knowledge about which device features (or levels of fidelity) are necessary to train particular skills.

<u>Identifying Underlying Tank Gunnery Skills</u>

Much of Armor training device research has focused on evaluating the overall training effectiveness of particular simulators, e.g., the Unit Conduct-of-Fire Trainer (U-COFT) (Hughes, Butler, Sterling, and Berglund, 1987) and the Simulation Networking (SIMNET) system (Gound and Schwab, 1986). Furthermore, device training effectiveness research has principally measured global outcome measures, e.g., Tank Table VIII scores. While these measures are useful for assessing overall proficiency, they provide little information regarding the underlying skills being trained. Global outcome measures also do not provide the level of specificity required to diagnose individual skill deficiencies.

Hughes et al. (1987) in the COFT Post Fielding Training Effectiveness Analysis (PFTEA) found that soldiers who had trained to higher levels in the U-COFT training matrix tended to have higher overall Tank Table VIII scores. The total scores were then analyzed separately for accuracy and speed, accuracy being assessed by probability of hits. Speed was measured by the crews' opening times, which for offensive engagements was the time from when the target appeared until the first round was fired. For defensive engagements, opening time began when the tank was exposed. The analyses showed that COFT training led to improvements in opening times but not in probability of hits, i.e., the crews became faster with additional COFT training, but not appreciably more accurate.

Formal Training Effectiveness Evaluations (TEAs) require the use of standard criterion measures such as Tank Table VIII in the <u>M1 Tank Combat Tables</u> or the tactical tasks and standards in the <u>Army Training and Evaluation Program</u> (ARTEP). For a variety of reasons, these measures may not be most appropriate for research designed to identify underlying skills or enhance training effectiveness. Hoffman (1989), for example, analyzed the FY87 Grafenwöhr Table VIII firing data and found a number of psychometrically disturbing relationships among the live-fire scores. Among these were that the distribution of scores was truncated at both the top and the bottom. The truncation meant that Table VIII scores had reduced variability and reliability relative to untruncated distributions. Of particular interest here is that the truncated scores meant that Table VIII largely did not discriminate among the high and low performers. By contrast, researchers interested in identifying underlying skills are particularly interested in the performance of those individuals who do exceptionally poorly or well.

Another problem with standard performance measures is that they are composite measures of multiple skills. Opening time, for example, while ostensibly a measure of speed, at a minimum assesses target acquisition, tracking, and procedural performance. An opening time of eight seconds can be accomplished through varying combinations of these skills, e.g., poor acquisition and good tracking or vice versa. The effectiveness of a device or the nature of appropriate feedback, for example for improving opening times, would likely vary depending on which skills most need training.

Also, while there may be hundreds of armor tasks, the number of underlying skills may be considerably fewer. Graham (1989a), for example, has found high intercorrelations between varying types of tank gunnery engagements which suggest that the same set of skills are required to perform a number of different tasks. Being able to perform a particular task or, conversely, making a particular type of error on a task, has implications for the performance of other tasks. Looking at the underlying skills, to include the types of errors being made, may be more informative than looking simply at whether a task can be performed. Having a better understanding of the skills that underlie the performance of various tasks can also result in more efficient training by permitting better predictions of training transfer.

Not all armor gunnery research has used probability of hits and opening times as criteria. Some recent research on the COFT has also used reticle aim accuracy as a measure of COFT gunnery proficiency. Witmer (1988) has argued that reticle aim accuracy, as measured by a combination of azimuth and elevation errors, may be a more sensitive measure of changes in gunnery proficiency than hits or opening time. Indeed, Campshure, Witmer, and Drucker (1990) found that relatively small amounts of COFT training for crews transitioning to the M1 tank resulted in significant changes in aiming error. The changes in reticle aim were not, however, large enough to affect overall measures of speed or accuracy. These results support the notion that aiming error may be a more sensitive measure of training than more global outcome measures.

One experimental approach that has been used to identify the underpinnings of performance is to compare the performance of masters to novices. In tank gunnery, Schmitz (1957) compared the tracking performance of trainees to tank gunnery experts while firing the 90 mm main gun on the M48 tank. He found that when firing at stationary targets from a stationary tank experts and trainees did not differ consistently in either reticle aim or in target hits. The majority of both the experts and trainees were also found to flinch, i.e., they closed their eyes or jerked the manual elevation handle when firing. The flinches did not, however, appreciably affect the reticle lay. Schmitz also showed that the vast majority of target misses were not due to the gunners' lay, but due to the dispersion of the gun and round.

While live-fire dispersion remains a problem today, the magnitude has certainly been reduced. Lindsley and Davis (1989) report that even while conforming to the "Fleet Zero Policy" (a policy they question), all of their battalion tanks hit a 2.2 x 1.75 m S-2 screening panel at 1200 m. Given less dispersion on the M1 series tank, it is not at all clear why targets are missed.

COFT Training and Testing

The Institutional Conduct of Fire Trainer (I-COFT) and U-COFT are high-fidelity tank gunnery simulators that along with live-fire have become the mainstay of tank gunnery training. Tank Commander (TC) and gunner controls on the M1 COFT are virtually identical to those in the actual tank, making the COFT analogous to flight simulators used in military and commercial training. The COFT simulates tank sight pictures with computer-generated imagery. The I-COFT and U-COFT are essentially identical with the exception that the I-COFT includes software options which can present individual training and computer-based tutorials.

In recent years COFTs have also been used in tank gunnery research because COFT tests can be constructed to measure a full range of target engagement tasks, including target acquisition, laying the main gun, and issuing fire commands. In addition, device-mediated tests with the COFT offer certain advantages over other hands-on performance tests. These pluses include standardized administration and scoring, and the capability of inexpensively building longer tests with varied target conditions. Research evaluating the reliability of testing on the U-COFT has found test-retest reliability coefficients which exceed .80 (Graham, 1986).

Purpose of Research

This research is designed to identify the underlying skill requirements of the tank gunner in armor gunnery tasks and to identify the particular skills that are trained by the I-COFT. This was primarily accomplished by observing changes in performance of novices with additional training and by comparing differences in performance between novices and masters. The performance analyses were based on the domain of armor gunnery crew behaviors identified by Morrison and Hoffman (1988). An experimental condition also was included to allow the comparison of performance on the I-COFT with performance on the U-COFT and to assess the effects of the I-COFT's automated capabilities on gunnery performance.

The objectives of the research were to:

1. Develop and refine analytical methods for identifying tank gunnery performance profiles on the I-COFT and for identifying the basis of tank gunnery errors;

2. Identify the gunner skills that are being trained on the I-COFT;

3. Compare the performance of tank gunnery novices and masters;

4. Compare the performance of experienced gunners on the I-COFT with performance on the U-COFT.

Method

Participants

The tank gunnery novice group consisted of 18 soldiers enrolled in Armor One Station Unit Training (OSUT) at Fort Knox, KY. These soldiers with ranks of private and private first class were from three companies in the 1st Armored Training Brigade and were participating in the Excellence in Armor (EIA) program. The EIA program accepts a maximum of 10% of highly selected volunteers from each OSUT company. EIA soldiers receive extra training, including 14 hours of I-COFT training, and peer leadership responsibilities. EIA soldiers also receive early promotions.

The tank gunnery masters were 10 Non-Commissioned Officers (NCOs) who were serving as gunnery instructors in the USAARMS Weapons Department. Each had extensive experience on the COFT. They had ranks of staff sergeant and sergeant first class.

COFT Test Construction

An I-COFT test was developed to assess changes in tank gunnery performance of the EIA soldiers. The I-COFT gunner's test developed specifically for this research contained four exercises taken from the I-COFT's Target Engagement Practice Exercises (TEPE). The exercises were selected with the assistance of the Tank Gunnery Training Branch, Weapons Department, USAARMS. Table 1 lists the exercises included in the test in the order of test presentation. The first exercise was a warm-up and was not scored. The 1-hr test required all targets to be engaged with the main gun. The test also employed the I-COFT's synthetic TC, an instructional feature whereby the software automatically acquires targets, lays the main gun, and gives fire commands. The synthetic TC, in effect, simulates a perfect TC in that it always gives correct fire commands and consistent target acquisition. All OSUT I-COFT gunnery training uses the synthetic TC, in part, because it eliminates the support requirement for a TC. For tank gunner testing purposes, the synthetic TC is thought to be ideal in that it helps ensure standardized testing.

A comparable test was also developed for the U-COFT. The I-COFT and U-COFT tests included the same exercises and exercise numbers with the exception that the fourth exercise number on the U-COFT test was 32411. The change in numbering was the result of a switch that was made in the U-COFT training matrix. The revised U-COFT training matrix trains own tank moving/stationary targets prior to own tank stationary/moving targets, i.e., reticle aim groups three and four have been switched. The U-COFT does not have the synthetic TC capability, so the participating NCOs also served as Tcs in the U-COFT test.

As a note, the 14 hours of EIA I-COFT training has the gunner fire exercises in an I-COFT matrix of preprogrammed exercises. Based on the gunner's performance in three areas, target acquisition, reticle aim, and system management, the computer recommends matrix advancement. The 14 hours of training allowed the EIA soldiers typically to progress to where they were firing at moving targets from a stationary tank. The entire matrix has 39 reticle aim levels. At the end of the 14 hours of EIA I-COFT training, progress ranged from reticle aim level 16 to reticle aim level 21.

Table 1

I-COFT Test Engagement Conditions

I-COFT Exercise Number	Number of Targets	Own Vehicle	Targets	Targets per Engagement
31311 (Warm-up)	5	Stationary	Short Range Moving	Single
32211	10	Stationary	Long Range Stationary	Single
33211	10	Stationary	Short Range Stationary	Multiple (2)
32311	10	Stationary	Long Range Moving	Single

COFT Testing Procedures

The EIA soldiers were given the I-COFT test twice. The first administration (Pretest) was during the last hour of their regular OSUT I-COFT training. The OSUT Program of Instruction calls for 20 hours of I-COFT training normally delivered within a two to three week period. The trainees are scheduled in pairs. Each soldier spends half of the time in the gunner's seat and half of the time observing, either in the TC's seat or beside the Instructor/Operator (I/O). Not all of the participating soldiers, however, received the full 20 hours. The amount of training ranged from 8 to 20 hours, although most received the full 20 hours. As part of the EIA training program, the soldiers received an additional 14 hours of I-COFT training. All of the EIA I-COFT training is in the gunner's seat. The second administration of the I-COFT test (Posttest) was given during the 14th hour of the EIA I-COFT training.

The NCOs were tested in pairs during normal duty hours. Half of the NCOs received the I-COFT test first followed by the U-COFT test, and vice versa. For the U-COFT test, one NCO was tested in the gunner's seat while the other served as TC. Upon completion, the two NCOs switched positions and the second NCO was tested as a gunner.

In summary, the EIA soldiers were tested twice; the Pretest was administered after normal OSUT I-COFT training and the posttest was administered after additional EIA I-COFT the training. The NCOs were also tested twice, once on the I-COFT and once on the U-COFT. The primary comparisons of interest were between the EIA Pre- and Posttests, the EIA Posttest and NCO I-COFT test, and the NCO I-COFT and U-COFT tests. A caveat is necessary. Because the design did not include a no training control group for the EIA soldiers, changes in EIA performance cannot be attributed specifically to the 14 hours of I-COFT training that occurred between the pre- and posttests.

COFT Data Collection

A tripod mounted mini-VHS camcorder was used to record the gunner's sight picture from the I/O station's gunner's view. The audio track on the videotape was used to record the I-COFT intercom, which included the synthetic TC fire commands, the gunner's communications, and comments to and from the I/O. A grid pattern and a digital stop watch were taped onto the I-COFT screen to facilitate scoring. The three standard COFT performance printouts were also collected.

COFT Data Analysis

Several types of information were extracted from the videotapes. First, each engagement was scored for timing, with three intervals being determined. The first interval, Acquisition Time, was from when the target appeared until the gunner reached the target with reticle. The second interval, Lase Time, was from when the reticle reached the target until the gunner lased with the laser range finder. The third interval, Fire Time, was from when the gunner lased until he fired. The sum of these three intervals equals the Opening Time for an engagement, i.e., from when the target appeared until the gunner fired. For engagements with multiple targets, Acquisition Time was only measured for the first of the two targets.

The videotapes were also reviewed to determine the reason rounds missed the targets. Each round that missed was attributed to either aiming, tracking, or procedural errors. Aiming errors consisted of aiming high, low, in front of, or in back of the target. Tracking errors included tracking too slow, too fast, erratic tracking, or wrong lead in system. Tracking too fast was characterized, for example, by the reticle moving in the same direction as the moving target but at a rate faster than the target. Furthermore for moving targets, an error was characterized as a tracking error rather than as an aiming error, if the reticle was on the target when the trigger was pulled and the round missed the target. For stationary targets, a tracking error was counted if there was lead in the system. Procedural errors included firing the wrong weapon at the target, having the wrong ammunition indexed, and failing to lase.

For moving targets, tracking performance for rounds that hit the target was categorized as either "good," "fair," or "poor." The tracking was characterized as "good" if the tracking rate was essentially the same as the moving target and the reticle was near center mass when the trigger was pulled. Tracking was categorized as "fair" if one of the two previous conditions were not met, i.e., either the tracking rate was appreciably different from the speed of the target or that the reticle was noticeably in front or back of center mass. A track was considered "poor" in situations where the gunner was basically lucky to have hit the target, e.g., major tracking and aiming errors offset each other.

The performance measures obtained from the COFT printouts included: probability of a hit, probability of a first round hit, opening time, and azimuth and elevation errors. Azimuth and elevation errors were the number of mils from center mass of the target that the round hit. A speed/accuracy composite, hit rate, was also computed similar to that developed by Hoffman and Witmer (1988). In this case, hit rate was simply the probability of a hit divided by opening time multiplied by 60 seconds. Hit rate can be interpreted as the number of targets that would be hit per minute; a higher hit rate represents faster, more accurate performance.

Hit rate was used to split the EIA soldiers into high, middle, and low performers for both the pretest and posttest. The soldiers with the six highest hit rates on the pretest were considered high performers, those with the next six highest hit rates were considered middle performers, and those with the lowest six hit rates were considered low performers. The soldiers were again separated into high, middle, and low groups on the posttest. Because the split was done twice, the six high performers on the pretest were not necessarily the same soldiers as the high six performers on the posttest. The NCOs were also split into high and low performers as a function of hit rate, with five in each group.

Results

Several analyses were performed which compared changes in performance within the group of EIA soldiers as the result of additional training. The performance of the EIA soldiers was also compared to that of the NCO gunnery masters. Other analyses examined the differences between the top and bottom performers in each of the groups. The purpose of the multiple comparisons were to identify those skills that are most related to performance at different levels of competency and to pinpoint the effects of COFT gunnery training. While none of the analyses may individually provide earth shattering insight, the goal is to document the relatively patterned development of skills and the differences between high and low performers.

Speed and Accuracy

Table 2 shows the speed and accuracy performance of the EIA soldiers at the end of normal OSUT I-COFT training (Pretest) and after the additional 14 hours of EIA training (Posttest). Paired group t-tests showed that EIA soldiers were considerably more accurate and faster on the posttest than on the pretest, with all five performance measures yielding increases of over one standard deviation in magnitude. As suggested in the methods section, the changes in performance cannot unequivocally be attributed to I-COFT training because of the lack of a control group. Effect size comparisons, i.e., where differences between means are described in standard deviation units, typically use the standard deviation of the control group as a reference. In this case, the standard deviation of the Pretest was used. An effect size of 1.0 is generally considered a large effect (Cohen, 1977). Note also that the standard deviations in the posttest are considerably smaller than the pretest indicating more consistent performance among gunners after the additional training.

Table 2 also shows the comparison of performance of the EIA posttest with the NCO gunnery masters. Statistical differences were found for all of the measures except for that of elevation error using independent group t-tests. Similar to the previous comparisons of Pre- and Posttests, the effect sizes are still relatively large with differences between the hits being around .75 and for opening time remaining around 1.5. Note here, however, that the standard deviations of the EIA Posttest and the NCOs are quite similar. Also, while the use of multiple t-tests results in finding more significant differences than truly exist, the intent of the analyses is to identify patterns in performance rather than absolute differences.

Table 2

EIA Pre- and Posttest and NCO I-COFT Test Performance

	PRETEST (n = 18)		POSTTEST (n = 18)		NCOs (n = 10)
		Paired t		Independent t	
Percentage Total Hits	.76 (.14)	-5.13**	.92 (.06)	-3.90**	.97 (.02)
Percentage First Round Hits	.68 (.13)	-6.10**	.87 (.06)	-1.84**	.91 (.06)
Opening Time	14.88 (1.61)	6.12**	12.63 (1.04)	3.39**	11.18 (1.12)
Azimuth Errors (mils)	1.01 (.31)	5.12**	.64 (.17)	2.96**	.48 (.12)
Elevation Errors (mils)	.56 (.26)	4.86**	.27 (.04)	-.92	.29 (.08)

Note. Standard deviations are in parentheses.

** $p < .01$

The results shown in Table 2 suggest that the NCOs are consistently faster and more accurate than the EIA soldiers. Tables 3, 4, and 5 separate performance on the I-COFT test by the different exercises. Table 3 shows the results of the first exercise of long-range single stationary targets.

As seen in Table 3, while there was improvement on all of the variables between the Pre- and Posttests, the only difference between Posttest and NCO performance was in Opening Time. The results suggest that for long range stationary targets, EIA soldiers at the end of training are as accurate as NCO gunnery masters. The effect size for opening time remains around 1.5. Note also that the EIA soldiers on the Posttest killed all of the targets, hitting 97% of the targets with the first round. In addition, the azimuth and elevation aiming errors are virtually identical for the two groups.

Table 3

EIA Pre- and Posttest and NCO Performance for Single Long-Range Stationary Targets

	PRETEST (n= 18)	Paired t	POSTTEST (n= 18)	Independent t	NCOs (n= 10)
Percentage Total Hits	.94 (.08)	-3.06**	1.00 (.00)	na[a]	.98 (.05)
Percentage First Round Hits	.85 (.14)	-2.97**	.97 (.07)	.93	.94 (.12)
Opening Time	15.06 (2.26)	6.26**	12.11 (.91)	2.21*	10.80 (1.74)
Azimuth Errors (mils)	.34 (.12)	2.94**	.26 (.06)	.10	.26 (.08)
Elevation Errors (mils)	.37 (.23)	2.67*	.22 (.05)	-.92	.26 (.13)

Note. Standard deviations are in parentheses. [a]t-test could not be computed because of zero variance in Pretest.

* $p < .05$. ** $p < .01$.

Table 4 shows that gunnery performance with multiple short-range stationary targets paralleled the pattern of gunnery performance on long-range stationary targets. The NCOs were faster than the EIA soldiers in firing at both the first and second targets in each engagement. The NCOs and EIA soldiers were equally accurate as measured by Percentage Total Hits, Percentage First Round Hits, and Azimuth and Elevation Errors.

Table 4

EIA Pre- and Posttest and NCO Performance for Multiple Short-Range Stationary Targets

	PRETEST (n= 18)		POSTTEST (n= 18)		NCOs (n= 10)
		Paired t		Independent t	
Percentage Total Hits	.82 (.16)	-3.93^{**}	.97 (.06)	-1.06	.99 (.03)
Percentage First Round Hits	.81 (.17)	-4.04^{**}	.97 (.06)	-.41	.98 (.04)
Opening Time First Target	13.53 (2.24)	2.91^{**}	11.82 (1.69)	2.61^{*}	10.57 (.84)
Opening Time Second Target	31.46 (2.67)	4.20^{**}	27.89 (2.49)	2.64^{*}	24.54 (3.55)
Azimuth Errors (mils)	.68 (.32)	4.50^{**}	.33 (.10)	.20	.33 (.07)
Elevation Errors (mils)	.66 (.40)	3.87^{**}	.31 (.07)	-.70	.34 (.10)

Note. Standard deviations are in parentheses.

$^{*}p < .05$. $^{**}p < .01$.

Table 5 shows that the NCOs were both faster and more accurate than the EIA soldiers on the long range moving targets. All of the performance measures are statistically different with the exception of elevation errors.

Table 5

EIA Pre- and Posttest and NCO Performance for Single Long-Range Moving Targets

	PRETEST (n= 18)	Paired t	POSTTEST (n= 18)	Independent t	NCOs (n= 10)
Percentage Total Hits	.51 (.28)	-4.55**	.78 (.16)	-4.54**	.97 (.05)
Percentage First Round Hits	.38 (.22)	-5.07**	.66 (.16)	-2.48*	.81 (.15)
Opening Time	16.06 (1.82)	4.62**	13.96 (1.29)	3.76**	12.17 (1.16)
Azimuth Errors (mils)	2.00 (.77)	4.04**	1.31 (.48)	3.15**	.84 (.31)
Elevation Errors (mils)	.65 (.47)	3.41**	.26 (.07)	-.31	.27 (.13)

Note. Standard deviations are in parentheses.

* $p < .05$ ** $p < .01$

Taken together, Tables 2 through 5 show that following the 14 hours of EIA I-COFT training the EIA soldiers were considerably both more accurate and faster than before the training. The comparison of the EIA Posttest to the NCOs showed that the NCOs were consistently faster than the EIA on both stationary and moving targets. Somewhat surprising is that differences in accuracy were found only for the moving targets. That there were no differences in accuracy on the stationary targets can be attributed, in a sense, to a ceiling effect. Considering, however, that several of the stationary targets had ranges in excess of 2600 meters, a better interpretation might be that given the controlled gunnery conditions in the I-COFT test, most gunners miss very few stationary targets.

The results thus far have shown that the skills needed to accurately hit stationary targets are trained rather quickly, but that the skills needed for speed develop more slowly. The focus of the next analysis is identify those speed components, or skills, that lead to differences in Opening Time.

Opening Times Analysis

As described earlier, Opening Time was partitioned into three time segments: Acquisition Time, Lase Time, and Fire Time. Table 6 shows these time segments for the EIA Pre- and Posttests and the NCOs separated by stationary and moving targets.

Table 6

Acquisition, Lase, and Fire Times for Stationary and Moving Targets

	PRETEST (n= 18)	Paired t	POSTTEST (n= 18)	Independent t	NCOs (n= 10)
Stationary Targets					
Acquisition Time	9.85 (1.56)	4.18**	8.57 (.87)	1.56	7.98 (.88)
Lase Time	2.91 (.88)	3.84**	2.11 (.73)	3.15**	1.39 (.48)
Fire Time	1.48 (.34)	2.37*	1.29 (.24)	-.43	1.32 (.18)
Opening Time	14.29 (1.76)	5.38**	11.96 (1.11)	2.69*	10.69 (1.26)
Moving Targets					
Acquisition Time	9.48 (1.00)	4.22**	8.43 (1.01)	.12	8.29 (.75)
Lase Time	4.12 (1.73)	2.37*	3.00 (1.26)	3.91**	1.66 (.54)
Fire Time	2.46 (.77)	-.30	2.53 (.83)	1.31	2.22 (.41)
Opening Time	16.06 (1.82)	4.62**	13.96 (1.29)	3.76**	12.17 (1.16)

Note. Standard deviations are in parentheses.
* $p < .05$ ** $p < .01$

The pattern of times are generally the same for both stationary and moving targets. The 14 hours of training between the Pre- and Posttests result in the EIA soldiers becoming faster in all three segments, with the exception of Fire Time on the moving targets. The soldiers are developing skills for quickly getting the reticle on the target, for quickly making a fine lay of the reticle on center mass, and for quickly firing after the TC has given a fire command.

Upon completion of EIA training, the only difference between EIA soldiers and NCOs is with regard to Lase Time, which is from when the gunner gets the reticle onto the target until he lases. Lase time primarily measures the ability of the gunner to make a fine lay of the gun through controlled tracking. The time required to get on the target, i.e., Acquisition Time, did not differ between the EIA Posttest and the NCOs. As described earlier the test employed the I-COFT synthetic TC which laid the gunner near the target and may have reduced target acquisition effects.

Skill Development Profiles

The results have shown that the various skills needed to engage stationary and moving targets develop at different rates. To better show the relative rates of skill development, the EIA soldiers were split into high, middle, and low groups and the NCOs were split into high and low groups. Figures 1, 2, and 3 show the performance of the groups on single stationary, multiple stationary, and single moving targets, respectively. The skill development profiles use solid lines to show means and dotted lines to show standard deviations. The X axis of each chart is arranged from low to high on the Pretest, low to high on the Posttest, and low to high for the NCOs. While the scale does not strictly represent a single ordinal dimension, it roughly portrays increasing skill levels. Skill level is loosely defined here as being a function of both amount of training and some underlying aptitude. The exact values shown in the figures, as well as the results of statistical tests, are included in Appendix A.

The intent of this analysis is to show the relative rates of skill development by examining the shapes of the curves for the various performance measures within the skill development profiles. Of primary interest is the point at which performance appears to asymptote, i.e., where there is no appreciable gains in performance at higher skill levels. If the asymptote is early, the skills assessed by that performance measure are thought to be quickly trained. Conversely, if the curve never asymptotes, then the skills assessed by that performance measure require considerable training to reach the top levels.

The skill development profiles for engaging single long range stationary targets are shown in Figure 1. As in each of the figures, the top four charts depict accuracy measures, namely percentage total hits, percentage first round hits, and azimuth and elevation errors measured in mils. The bottom four charts depict the measures of speed. Skills needed for accuracy on the long range stationary targets begin to asymptote very quickly. Figure 1 shows that all four accuracy measures reach their peak during the Pretest which again was administered at the end of normal OSUT I-COFT training.

Performance speed as represented by Opening Time continues to improve across the entire range of skill levels. Whereas Fire Time improves little across the skill levels, Acquisition Time and Lase Time continue to improve. Note that the Acquisition Times for all three performance levels on the posttest are marginally faster than the low NCOs. The EIA soldiers had just completed a week of intensive training on the I-COFT. The differences in Acquisition Time may represent COFT-specific skills in that the EIA soldiers had great familiarity with the I-COFT while the NCOs had little experience firing with the synthetic TC.

The same pattern of skill development profiles are shown in Figure 2 for the multiple short range stationary targets. Accuracy skills asymptote early and speed skills continue to develop across the skill levels. This pattern is consistent with TopGun speed and accuracy scores recently shown by Hart, Hagman, and Bowne (1990). Note in the bottom right chart (Opening Time 2) that there is a sharp improvement with the high NCOs in the time required to engage the second target in each engagement. The results suggest that hit rate or engagement speed for multiple target engagements are more sensitive measures of performance proficiency than are single target engagements for skilled gunners. This finding supports the design of Tank Table VIII which contains a majority of multiple target engagements.

Figure 3 shows the skill development profiles for engaging long range moving targets. With the single exception of elevation errors, the accuracy measures continue to improve across the range of skill levels. Note that the high EIA soldier are about as accurate as the low NCOs, but that the high NCOs are more accurate. For the speed measures, there is again improvement across full range of skill levels. Given that both speed and accuracy skills continue to improve for moving targets, it is reasonable that a majority of gunnery training should train the engagement of moving targets. Also, tests designed to assess the performance of skilled gunners would likely be more discriminating if they included mostly moving targets.

One somewhat surprising pattern is found in the Lase and Fire Times for the NCOs. The low and high NCOs were equally fast in Lase Time, i.e., the time from when they got on the target until they lased, with both groups being faster than the high EIAs. The high NCOs were considerably faster in Fire Time which is the time from when they lased until they fired. The unusual pattern for posttest Fire Times is caused by one outlier in the EIA middle performers group. The high NCOs were apparently better able to hold the proper track after the lase than were the low NCOs. This will discussed in greater detail in a later section on tracking procedures and errors.

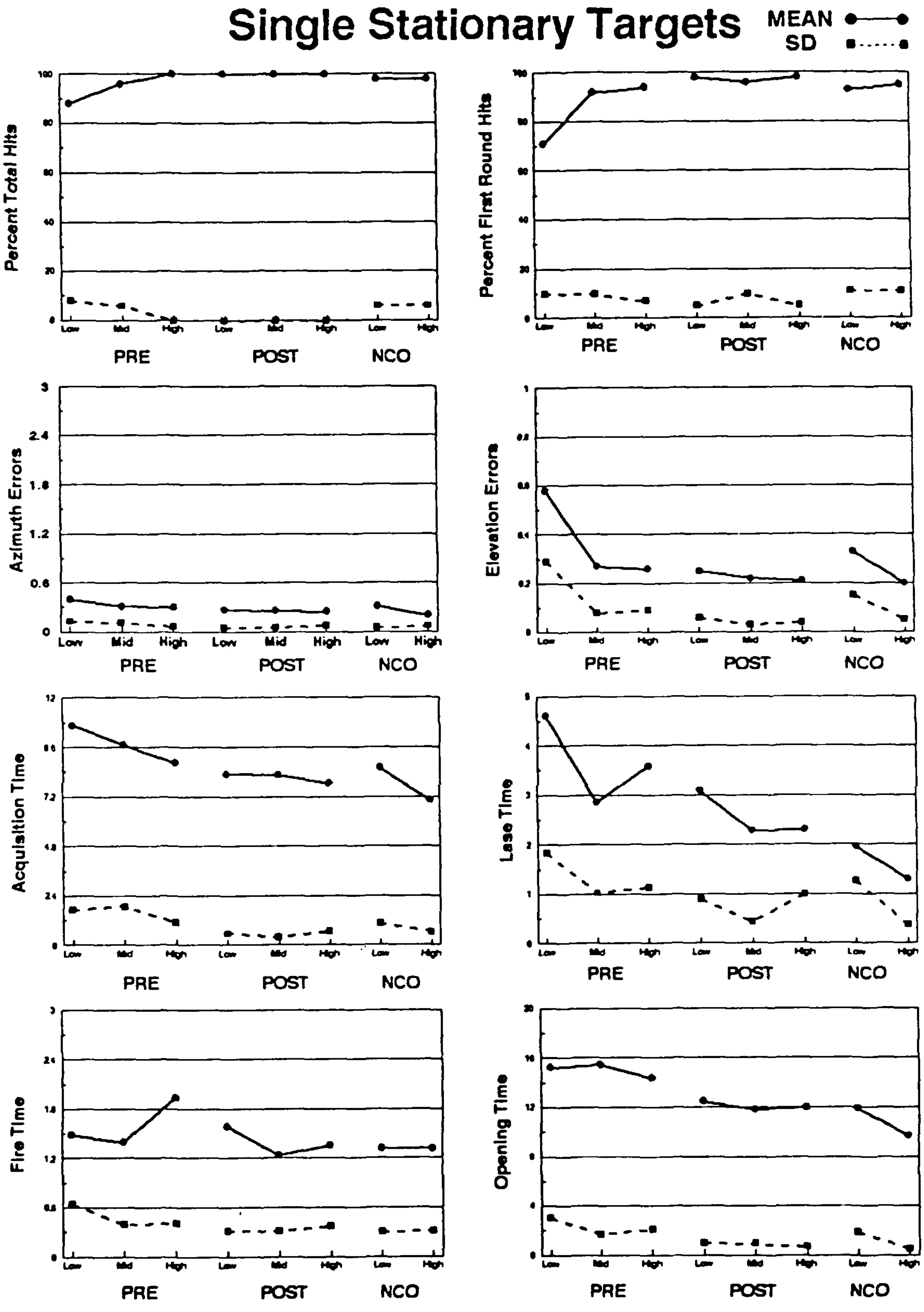

Figure 1. Skill development profiles for long-range stationary targets

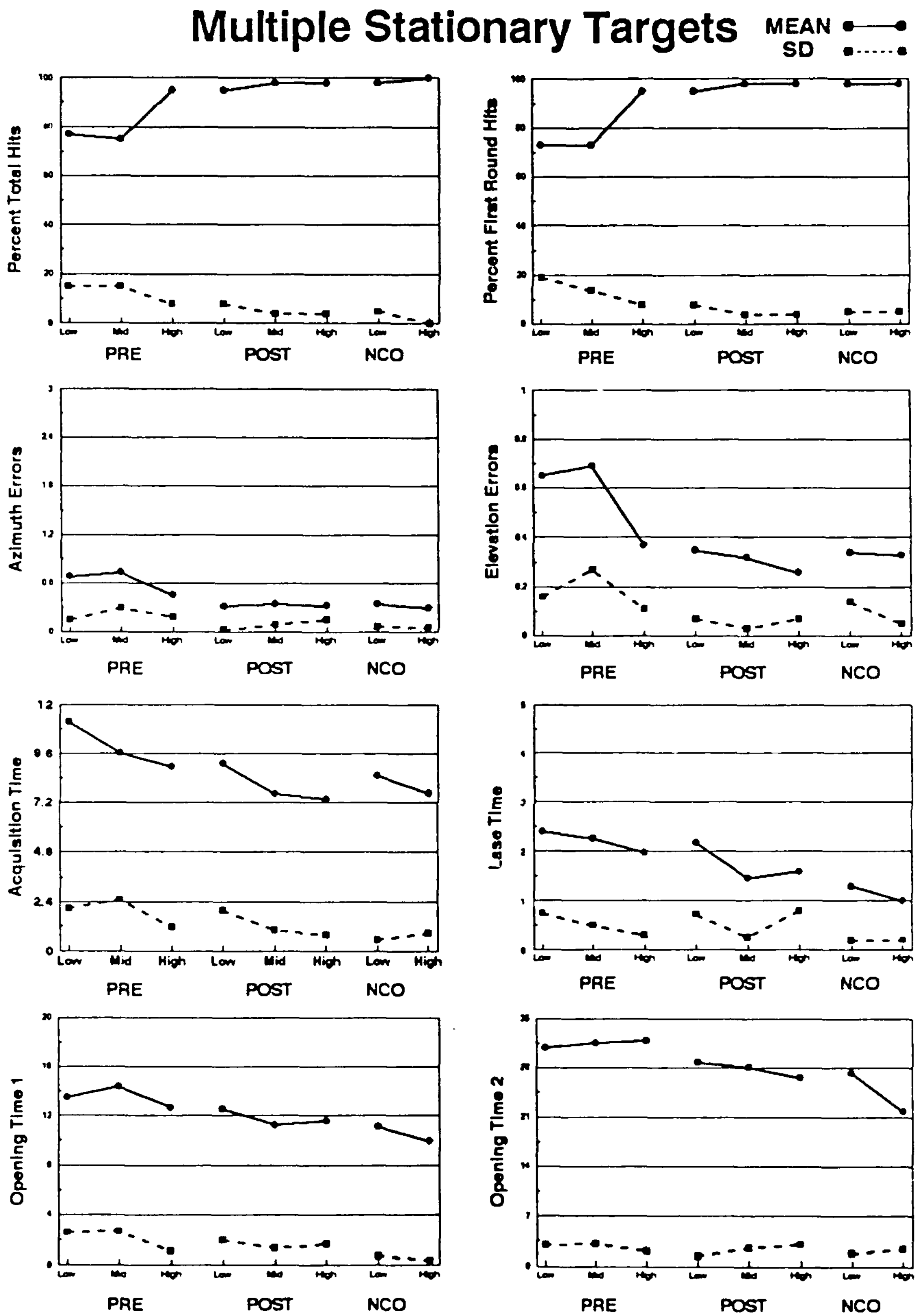

Figure 2. Skill development profiles for multiple short-range stationary targets

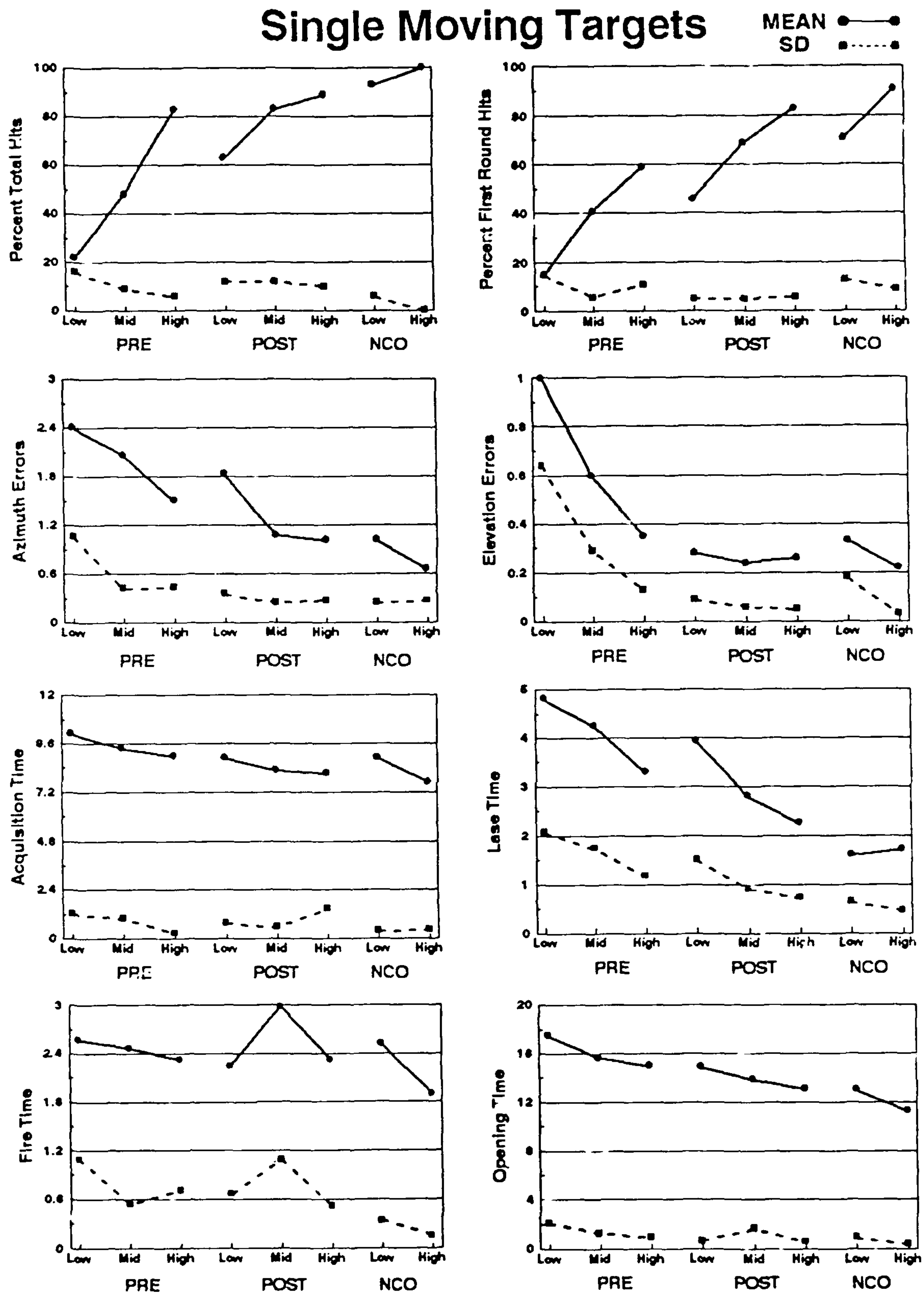

Figure 3. Skill development profiles for long-range moving targets

Hit Rate Comparisons

Figure 4 shows a comparison of the overall Hit Rates for the EIA Pre- and Posttest and for the NCOs. Recall that the test included an equal number of single long range stationary, multiple short range stationary, and single long range moving targets. Overall Hit Rate therefore represents an equal proportion of these types of targets. Hit Rate can roughly be interpreted as the number of targets that would be hit per minute in a target rich environment. The results show that as expected Hit Rate continues to improve across the range of skill levels. What is interesting is that the top two thirds of EIA soldiers, i.e., high and middle combined, have almost the same mean Hit Rate (4.75) on the posttest as the bottom half of the NCOs (4.76).

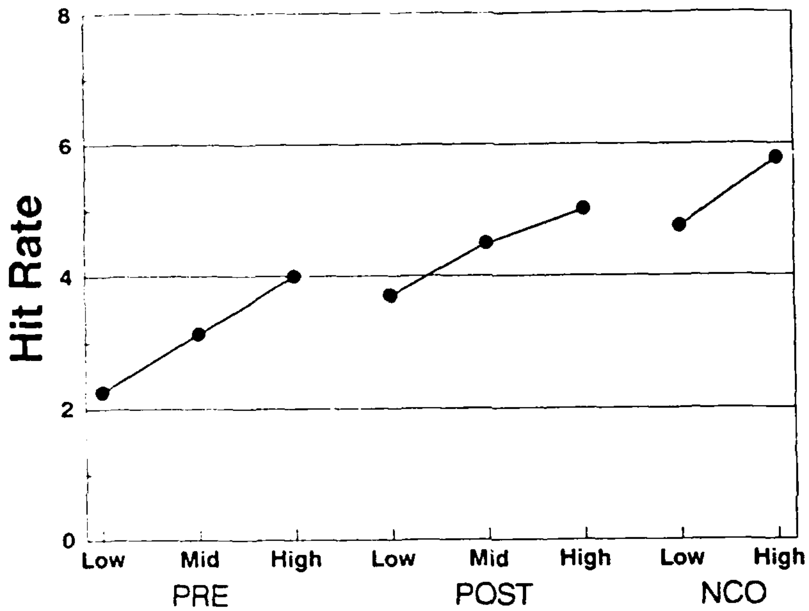

Figure 4. Hit Rates for EIA Pre- and Posttests and NCOs

That the Hit Rates are equivalent is not to imply necessarily that the higher EIA soldiers are as good of gunners as the low NCOs, for at least two reasons. Foremost, being a good gunner requires a number of skills and knowledges other than being able to shoot the main gun, for example, crew-level maintenance. Like wisdom, many of these skills and knowledges are only developed through varied hands-on experiences within armor units. Secondly, the I-COFT test only assessed gunnery performance in normal operational mode; it is not known whether the EIA gunners could perform as well as the NCOs in the degraded mode.

Previous research has shown that EIA soldiers have higher gunnery aptitudes than the OSUT population as a whole. Graham (1989b) administered a similar I-COFT test to 479 19K OSUT soldiers at the end of normal OSUT I-COFT training and found that soldiers selected for EIA had hit rates about 3/5ths of a standard deviation above the entire OSUT sample. That large of a difference means that the 50th percentile of the EIA population is equivalent to the 72nd percentile of the entire OSUT population. The research also showed that it was possible to identify with considerable accuracy the best I-COFT gunners through the use of a spatial and psychomotor test battery. The spatial and psychomotor predictor tests, originally developed by ARI as part of Project Alpha, were administered at the reception station and prior to any OSUT training.

While the EIA soldiers were better than the whole OSUT population, the NCO gunnery instructors were also probably better than NCOs as whole in gunnery. It is possible that the performance level of the lower half of the NCOs is a better indicator of average NCO performance level. In interviews with the NCOs (Graham, in preparation), several reported having had an extraordinary amount of COFT training, . All told, the results show that for normal mode tank gunnery, young soldiers with high aptitudes can be trained up near to the level of NCOs in a relatively short period of time. This is, of course true only if high quality training resources such as the COFT are made available.

Comparison of I-COFT and U-COFT Performance

The comparison of I-COFT and U-COFT performance was made to assess the impact of the synthetic TC on the gunnery performance of experienced gunners. In principle, the synthetic TC is ideal for gunnery testing in that it is makes consistent lays and fire commands. Previous research has shown that the TC has a large effect on performance measures designed to assess the gunner (Graham, 1986). If, however, there are differences between the performance patterns of experienced gunners when using the synthetic TC as compared to a live TC, the validity of results using the synthetic TC is sharply reduced.

Overall, there were few differences between the performance of the NCOs on the I-COFT as compared to the U-COFT. As a reminder, the I-COFT and U-COFT are the same piece of hardware, the difference being here that the I-COFT used the synthetic TC and the U-COFT used a live TC. As would probably be expected no differences were found in the accuracy measures. For example, the mean percentages of first round hits for the I-COFT and U-COFT on stationary targets were .96 and .95, and on moving targets were .79 and .81, respectively. Refer to Appendix B for all the I-COFT and U-COFT comparisons.

There were several differences in the speed of performance. The Opening Times on the I-COFT tended to be faster than on the U-COFT with significant differences being found for single stationary and single moving targets. For example, on single stationary targets, the I-COFT and U-COFT Opening Times were 10.8 and 12.3 seconds, respectively ($t(9) = 2.49$, $p<.05$). An analysis of the opening time segments shows that it was acquisition time that accounted for the differences, i.e., from when the target appears until the gunner moved the reticle to the target. The mean acquisition times, for example, for I-COFT and U-CCFT on the single stationary targets were 7.8 and 9.4 seconds ($t(9) = 3.12$, $p<.05$). The synthetic TC was able to slew to the target quickly because the computer "knows" where the target is located. By contrast, the TC and gunner in the U-COFT had to first scan, locate the target, and then slew.

For two of the variables, there were time advantages for the U-COFT. On the multiple stationary targets, the time to fire at the second target (Opening Time 2) was considerably faster on the U-COFT than on the I-COFT, with means of 17.7 and 24.4 seconds, respectively ($t(9) = 10.86$, $p<.001$). The I-COFT software is structured such that unless the first target is killed very quickly, the tank moves back into a defilade position. Before the second target can be engaged, the tank must move back up into a hull-down position. On the U-COFT, the gunners were always able to engage both targets before going back to a defilade position.

The Fire Times, i. e., the time from when the gunner lased until he pulled the trigger, were also faster on the U-COFT than the I-COFT on the multiple stationary targets. The mean Fire Time for the U-COFT was .9 seconds while the mean Fire Time for the I-COFT was 1.3 seconds, ($t(9) = 2.40$, $p<.05$). These targets were at short range and were therefore relatively easy to hit. On both the U-COFT and the I-COFT, the gunner must wait until the TC says "fire", before pulling the trigger. On the short range targets, the U-COFT Tcs were able to more quickly assess the accuracy of the lay and say "fire" than was the I-COFT's synthetic TC.

While the latter analysis demonstrates the effect of the TC on overall crew performance, the majority of the U-COFT test variance was due to the gunner. Gunnery performances on the I-COFT and U-COFT were quite similar, even though the Tcs varied between synthetic and NCO. The correlation between I-COFT Hit Rate and U-COFT Hit Rate was .79, with the correlation between I-COFT and U-COFT Opening Time being .75. I-COFT and U-COFT Percent Hits were not correlated probably because of ceiling effects. The high correlation between performance on the I-COFT and U-COFT further support other research which has demonstrated the COFT to be a reliable testing device. Also, the high correlation suggests that in the current situation the TC had only a minor impact on the performance of the gunner. Given the experience of the NCO TCs, all of their performances may have approximated the synthetic TC.

The comparison of performance on the I-COFT with performance on the U-COFT was requested by the Director, USAARMS Weapons Department because it was believed that the slowness of the synthetic TC would adversely affect the performance of experienced tankers. This was, however, generally not found. One reason is that a recent change to the I-COFT software has resulted in faster actions by the synthetic TC. Secondly, while the synthetic speech capability of the I-COFT, not so affectionately referred to as "Bubba," is generally slow, the slowness cannot be attributed to the synthetic TC during the actual engagements. By contrast, the speed of the synthetic speech for giving exercise instructions is annoyingly slow to the point of apparent training inefficiency.

Error Profile Analyses

While the focus of this research is primarily on identifying those skills needed for successful tank gunnery performance, the following analyses examine what the gunner improperly does when he misses targets. If certain patterns of errors can be identified at different points in training, then training could be tailored to enhance the skills needed to avoid those types of errors. Also, while the idea behind these analyses is straightforward, the results are currently generally unknown and perplexing. For example, given a $2.5 million tank with a computerized fire control system, how does a gunner miss a short range stationary target?

The error analyses shown in Tables 7 and 8 examined each round that failed to hit the target and categorized those misses as being due to aiming, tracking or procedural errors. For example in Table 7, 7% of the rounds fired in the pretest resulted in aiming errors. Within each error category, the proportion of misses of a particular type (or relative pattern) are indicated in brackets. Also shown are the number of bad lases relative to the number of targets. A bad lase can be either a multiple return, flashing zeros, or an incorrect range. Table 7 shows the error profiles for the EIA Pre- and Posttest and for the NCOs for the long range stationary targets.

Table 7 shows that for the Pretest roughly an equal number of the misses were due to aiming and procedural errors. The nature of procedural errors varied on the pretest, but in effect were non-existent on the Posttest and with the NCOs. While admittedly the numbers here are small, the data corroborate the notion that the COFT is a very good procedures trainer. That there were a number of misses caused by firing with a bad lase is understandable. A likely explanation is that the attention of the gunners was so narrowly focused on aiming the reticle that they did not even look at the range, e.g., flashing zeros, even though it was at the bottom of the sight picture.

Somewhat surprising is that virtually all of the misses were due to aiming high or low. This was probably due largely to the shape of the targets which were essentially rectangular with longer bases than heights. Referring back to Table 3, we see that the mean azimuth and elevation errors were roughly the same at all levels. Given the target shapes, deviations around the mean of elevation errors caused more misses than deviations around the mean of azimuth errors. The value of these results may be in making soldiers aware that their aiming errors tend to be high and low. Additional attention to the elevation of the reticle could lead to significantly fewer misses of stationary targets. These data also support the need and trend to decrease the height of armor vehicles.

Note also that the number of lase errors on the pretest was greater than the number of misses. This is due in part to the fact that lase errors on the COFT help reduce the number of misses on stationary targets. If a gunner has a good lase, he will most likely hit the target, with the exceptions being due to dispersion. If the gunner does not have a good lase, he is in effect cued by the synthetic TC to relay the reticle. Nevertheless, the novice gunners should be made aware that they tend to be more sloppy in their reticle aim prior to lasing than prior to firing. A number of the lase errors were due to the gunner lasing helicopter targets in the tail; this seemed to always result in a multiple return.

Table 7

Error Profile for Single Long-Range Stationary Targets

	PRE	POST	NCO
Number of targets	144	144	80
Rounds fired	153	149	85
Number of targets hit	133	144	79
Target hits per round	.87	.97	.93
Targets not engaged	0	0	0
Aiming errors	7%	3%	5%
High	[33%]	[60%]	[50%]
Low	[50%]	[40%]	[50%]
Left	[8%]	-	-
Right	[8%]	-	-
Tracking errors	0%	0%	0%
Jerked controls	-	-	-
Lead in system	-	-	-
Procedural errors	6%	<1%	2%
Fired with bad range	[44%]	-	-
Wrong weapon	[11%]	-	-
Did not lase	[22%]	-	-
Wrong Ammo indexed	[22%]	-	-
Weapon not armed	-	-	-
LRF switched wrong	-	[100%]	[100%]
Bad lases relative to number of targets	14.2%	2.0%	1.2%

Table 8 shows the error profiles for the multiple short range stationary targets. The most obvious point is that short range stationary targets are rarely missed on the COFT. These engagements averaged 1250 meters. On the pretest there were some aiming errors, and like the long range stationary targets, most of these errors were due to aiming high or low. Several of the errors on the pretest resulted from the gunner having lead in the system. In these cases, the gunner failed to dump the lead from the system after engaging the first target. The necessity for sometimes dumping lead will be discussed later. Note, however, that there were only a few of these types of errors, with none on the posttest or with the NCOs.

Table 8

Error Profile for Multiple Short-Range Stationary Targets

	PRE	POST	NCO
Number of targets	180	180	100
Rounds fired	164	175	101
Number of targets hit	148	175	100
Target hits per round	.91	1.0	.99
Targets not engaged	13	5	0
Aiming errors	5%	0%	0%
High	[22%]	-	-
Low	[67%]	-	-
Left	-	-	-
Right	[11%]	-	-
Tracking errors	2%	0%	0%
Jerked controls	[33%]	-	-
Lead in system	[67%]	-	-
Procedural errors	2%	0%	1%
Fired with bad range	[33%]	-	-
Wrong weapon	[33%]	-	-
Did not lase	[33%]	-	-
Wrong Ammo indexed	-	-	[100%]
Weapon not armed	-	-	-
Bad lases relative to number of targets	6.2%	0.6%	1.0%

In addition to the number of rounds that missed the targets, an even greater number of targets were not engaged. This was generally due to poor target acquisition skills, whereby the gunner took so long to find the first target that the second target moved away before he could engaged it.

<u>Target tracking procedures and errors.</u> Prior to presenting the error profiles for the moving targets, it is useful to discuss normal mode main gun

tracking procedures on the M1 tank. For this discussion, imagine a tank at 1600 meters moving from left to right. Beginning with the handoff from the TC, the gunner squeezes the palm switches on the power control handles; this enables the tank's stabilization system. At this point, there is no lead in the system. The gunner then rotates the power control handles to get the reticle on the target and to track at the same speed as the moving target. The power control handles function similarly to the steering wheel in a car. The farther you rotate the handles from the center position, the faster the gun tracks.

If you are tracking the same speed that the target is moving, the reticle appears stationary relative to the moving target. After tracking at the same speed as the target for some period of time, the gunner pushes the laser range finder button on the handle with his index finger. The M1 Operator's Manual (TM 9-2350-255-10-2) states that it takes three seconds of tracking to get the correct lead inserted into the system. The Lase Time data in Figure 6 show that NCOs do not wait a full three seconds. Lasing causes lead to be introduced into the system. As the lead is inserted, the entire sight picture noticeably shifts in the opposite direction of the target's movement. In our example, the sight picture would shift to the left. It takes the gun approximately 3/10ths of a second to catch up with the sight during which time there is a slight jitter in the sight picture.

If the gunner (1) has been tracking at the same rate as the target when he lased, and (2) was at center mass when he lased, and (3) continued to hold the control handles in exactly the same position, the reticle would continue to be in the center of the target and tracking at the same speed, even though the entire sight picture had moved. The gunner should then check the bottom view of his gunner's primary sight to see if his range is correct, that there is no multiple return bar nor a fault indicator, and that he has a ready to fire symbol. Assuming everything is alright and that the TC has said "fire," the gunner would then pull the trigger. Upon killing the target, he should release his palm switches which dumps the lead, i.e., takes the lead out of the system until he or the TC lases again.

What usually happens, however, albeit to different extents, is that when the gunner lases and the sight picture displaces, the gunner moves the power control handles and therefore changes the tracking rate. The ballistic computer, instead of holding the constant tracking rate that was inserted when the gunner lased, begins updating the tracking rate. The computer apparently uses a smoothing function that averages the old tracking rate to the new tracking rate at some update frequency. If the tracking adjustments are small, the effects are manageable, if not negligible. For example, if after lasing the gunner starts to track a little faster, the sight picture smoothly shifts, in our example, a little farther to the left. If, however, the gunner makes a dramatic adjustment, the computer likewise begins making dramatic corrections in the tracking rate. The effect is that the reticle looks something like it is being dragged by an extended rubber band. The result normally is erratic tracking. What the gunner should do in this situation is dump the lead and relase.

Recall the differences in Lase Time between the high and low NCOs. The results suggest that the high NCO performers were able to hold a constant track during and following the lase. The high NCOs fired in less than two seconds after they lased. By contrast, the low NCO performers required an additional 6/10ths of a second to re-track the target following the lase.

As a note, the M1A2 tank will stabilize the mirror in the gunner's primary sight for changes in azimuth. Currently only elevation is stabilized in the mirror with azimuth being stabilized as part of the turret stabilization. The result of the mirror stabilization will be that the reticle will no longer displace when lead is inserted into the system. Based on the observations made in this research, it is reasonable to expect that this M1A2 change will increase both accuracy and reduce kill times for long range moving targets. With the possible exception of the best gunners, i.e., the high NCO performers, the movement of the reticle adversely affected the gunners' track of the target.

The error profiles for the long range moving targets are presented in Table 9. Not surprisingly, the majority of the moving target misses resulted from tracking errors. Also, unlike with the stationary targets the frequency and pattern of errors differ between the EIA posttest and the NCOs. In the pretest many of the tracking errors were due to erratic tracking. Erratic tracking was characterized by the reticle swinging back and forth across the target and, again, was generally caused by the gunner making too large of adjustments with the gunner's control handles.

By the end of the 14 hours of EIA training, the erratic tracking had largely disappeared. On the posttest, half of the tracking errors were due to the gunner tracking too slow. By contrast, 88% of the NCO's tracking errors were that they were tracking too fast. Tracking too fast in the NCOs was typically characterized by the gunner falling behind the center of the target, i.e., he was tracking too slow. He then sped up the track and fired as the reticle approached the center of the moving target. Because the tracking rate would then be faster than the target was moving, the round would fall in front of the target.

Providing this type of information to the COFT instructors and to the soldiers training gunnery skills should enhance training effectiveness. It is quite likely that the gunners are unaware of their tendencies that result in errors. Clearly certain types of performance feedback are given now, but there is good reason to suspect that the quality of the feedback varies between COFT trainers. Furthermore, the performance information readily printed out by the COFT may not be sufficient. For example, the COFT printouts indicate whether the rounds fell to the right or left of the targets, this information is not particularly helpful for moving targets, because it ignores the direction the target is moving.

Generally then, the pattern of tracking errors moved from being erratic to tracking too slow to tracking too fast. This pattern is further substantiated by the data in Table 10 which show the tracking errors broken down by the high, middle, and low performers on the pretest and posttest. The tracking errors of the high performers look like those of the NCOs, i.e., they generally tracked too fast. Also, these data further demonstrate that developing the skills necessary to track and kill moving target requires considerable time to develop for some soldiers. Note that the low group is still making near 50% tracking errors after the EIA training.

Table 9

Error Profile for Single Long-Range Moving Targets

	PRE	POST	NCOs
Number of targets	162	162	90
Rounds fired	206	208	106
Number of targets hits	83	127	87
Target hits per round	.40	.61	.82
Targets not engaged	5	1	0
Aiming errors	10%	6%	2%
High	[40%]	[20%]	[50%]
Low	[22%]	[25%]	[50%]
Front	[25%]	[30%]	-
Back	[8%]	[25%]	-
Tracking errors	46%	32%	16%
Too fast	[33%]	[35%]	[88%]
Too slow	[40%]	[49%]	[12%]
Erratic	[23%]	[9%]	-
Ambush	[3%]	-	-
Dumped lead	-	[7%]	-
Procedural errors	4%	<1%	0%
Fired with bad range	[38%]	[100%]	-
Wrong weapon	[13%]	-	-
Did not lase	[13%]	-	-
Wrong Ammo indexed	[25%]	-	-
Weapon not armed	[13%]	-	-
Bad lases relative to number of targets	22%	6%	7%

The data can also be taken as indirect evidence for the large extent that underlying general skills or aptitudes account for the proficiency of tracking moving targets. Note that the high performers on the pretest made a lower percentage of tracking errors than either the low or middle performers on the posttest. This is not to suggest that the low performers cannot become proficient in gunnery, but that some individuals will require more training than others. This finding is consistent with the results of Graham (1989b) that showed psychomotor and spatial test performance was a strong predictor of COFT gunnery performance, particularly for killing moving targets. That is, those individuals who demonstrated on a relatively short test that they had what is often referred to as good eye-hand coordination were predictably better on the COFT.

Table 10

Tracking Error Profiles for Moving Targets

	EIA SOLDIERS						
	LOW		MIDDLE		HIGH		NCOs
	PRE	POST	PRE	POST	PRE	POST	
Percentage tracking errors	66%	47%	42%	36%	30%	12%	16%
Too fast	[23%]	[27%]	[38%]	[36%]	[42%]	[67%]	[88%]
Too slow	[46%]	[52%]	[34%]	[52%]	[38%]	[20%]	[12%]
Erratic	[27%]	[9%]	[24%]	[12%]	[10%]	[0%]	[0%]
Ambush	[4%]	[0%]	[3%]	[0%]	[0%]	[0%]	[0%]
Dumped lead	[0%]	[11%]	[0%]	[0%]	[0%]	[13%]	[0%]

Several of the other types of errors require discussion. One soldier consistently tracked well but released the palm switches prior to firing, i. e., he dumped the lead. The result was that he missed most of the targets. Also, several of the EIA soldiers on the pretest tried to ambush the moving targets. Ambushing refers to moving the reticle out in front of the moving target and waiting for the target to approach the stationary reticle. This practice is highly discouraged and ineffective. Note that none of the EIA soldiers ambushed on the posttest, nor did any of the NCOs. It is possible that ambushing may still occur in units, particularly with soldiers who have transitioned from tanks that did not have a sophisticated fire control like the M1. Proponents of OSUT/EIA COFT training believe that the early gunnery training is important because it trains future gunners correct gunnery procedures from the start. As a result, they never develop bad habits like ambushing. These data support that contention.

<u>NCO performance with evasive targets.</u> The new software used in the U-COFT test serendipitously contained two helicopter targets which were unlike any COFT targets the NCOs had previously seen. Previously COFT helicopters (or choppers) had been relatively easy to hit as they were larger than tank targets, and moved slow and in straight lines. The new chopper targets fly at realistic speeds around 100 mph and also change direction and elevation. In general, tankers are now trained not to engage helicopters unless they are attacking. The reason is that they are too hard to kill and engaging reveals the tank's location.

Table 11 shows the error profile for the evasive helicopter targets by the high and low NCOs. Most striking is that only 6 of 44 (14%) rounds hit the target. Also while the high performers hit 18% as compared to 9% for the low performers, their error patterns were quite similar. Both groups had 18% aiming errors which were all high or low and most of the tracking errors were again from tracking too fast. One of the two helicopters flew behind a barn and as it emerged it turned and hovered, facing the tank. The helicopter then turned and again flew following the elevation of the terrain. Many other COFT targets similarly go behind buildings and the soldiers are trained to continue a smooth track on the vehicle and wait for it to emerge. When the helicopter quickly stopped and turned, however, the gunner had to change directions to get back on the target. At this point the gunner needed to drop the lead. As can be seen in the table, a number of gunners failed to drop lead when the target stopped, both from the high and low groups.

In a number of engagements, the gunners were doing everything correctly and still missed the target. The helicopters were at ranges of around 2200 meters which means the rounds took nearly two seconds to fly down range. There were cases where the helicopters changed elevation sufficiently between when the round was fired until it reached the target to have caused high/low aiming errors. On the other hand, the NCOs should have known or have been trained to drop lead when the target stopped moving. The NCOs had not, however, trained on these types of targets and therefore were not prepared for evasive targets. The performance on these targets raises questions about the adequacy of standard gunnery exercises for assessing combat proficiency. Tank Table VIII, for example, has highly predictable targets.

Table 11

Error Profile for U-COFT Evasive Helicopter Targets by High/Low NCO Split

	NCOs Low	NCOs High
Number of targets	10	10
Rounds fired	22	22
Targets Hit	2	4
Aiming errors High or Low	18%	18%
Tracking errors	77%	64%
Too fast	[75%]	[57%]
Too slow	-	[7%]
Failed to dump lead when target stopped	[25%]	[36%]

Tracking Profiles

The results thus far have consistently demonstrated the importance of good tracking skills for fast accurate performance on both the stationary and moving targets. To further assess the importance of tracking skills, each successful track of a moving target, i.e., those that resulted in a kill, were rated as either good, fair, or poor. "Good" tracks were essentially picture perfect, in that tracking rate was the same as the target and the reticle was near center mass of the target. "Fair" tracks were when either the tracking rate was too fast or too slow or that the reticle was appreciably off center mass. "Poor" tracks were when both tracking rate and reticle aim were off. A poor track that resulted in a hit may have been where the errors offset each other.

Clearly these ratings were subjective, albeit rule based. Also, the ratings were not completely independent in that they were performed by one individual and a soldier at a time. Nevertheless it was fairly easy to place the tracking performances into three categories. Also, the tracking ratings generally only rated the track immediately prior to the trigger pull. For example, a "good" track may at first have been erratic, but that the gunner got the track under control and had a steady track at the same rate as the target with a good aim prior to pulling the trigger. Table 12 shows the tracking ratings broken out by the high, middle and low performers, The numbers represent the percentage of the total number of moving targets presented rated in that category for a particular group. For example, 7% of the moving targets on the pretest were rated as having been had good tracks for the low EIA performers.

Table 12

Tracking Profiles for High, Middle, and Low EIAs and NCOs

	Percent of Total Targets		
	GOOD	FAIR	POOR
Pretest			
Low	7%	9%	6%
Middle	13%	20%	15%
High	28%	43%	13%
Posttest			
Low	17%	35%	11%
Middle	33%	33%	15%
High	41%	43%	7%
NCOs			
Low	51%	38%	4%
High	82%	16%	2%

The tracking ratings show that the tracking performance of all soldiers increased considerably between the pre- and posttests. Perhaps the most interesting result is that the low NCOs only demonstrated good tracks on half of the engagements. This suggests that "good" tracking, which is actually excellent tracking, takes either a large amount of training, high aptitudes, e.g. general psychomotor and spatial skills, or more likely, both.

It is possible that the M1 fire control system is forgiving enough that it does not require excellent tracking to hit targets. That is, the amount of tracking error created by the "fair" tracks might have an insignificant effect for gunnery on the full domain of targets, e.g., stationary, moving, single, and multiple. To test the impact of the tracking ratings on overall performance, a regression analysis was performed to assess the impact of tracking on overall performance. The results of the analysis are shown in Table 13. The analysis predicted Hit Rate across the pretest, posttest and NCOs, i.e., the three distributions were combined. Recall that Hit Rate was a speed/accuracy composite. The predictors were the number of tracks that were rated Good, Fair, and Poor.

Table 13

Regression Analysis Predicting Hit Rates from All Tests with Good, Fair, and Poor Tracking Ratings

Criterion: Total Test Hit Rate

Multiple R = .86 Multiple R^2 = .74

Predictors	Beta	T	Sig. T
Good	.95	11.3	.000
Fair	.48	6.4	.000
Poor	.26	3.2	.003

The results show that the tracking ratings did an excellent job of predicting overall I-COFT performance. What this means is that by observing how well a gunner tracks a set of moving targets, it is possible to predict how he would do on moving and stationary targets for both speed and accuracy. Note also that the relative contributions of the Good, Fair, and Poor tracks as indicated by the Beta weights were approximately 4:2:1. Future research might assess the stability of this weighting for developing performance measures or predictors.

Speed or Accuracy Predominance

A common finding within performance assessment is that of a speed/accuracy tradeoff whereby increases in speed are typically associated with an increase in the number of errors. The tradeoff generally refers, however, to speed/accuracy strategies employed by one particular individual. On a particular engagement, for example, a soldier may choose to be a little faster or a little more cautious and hence more accurate. Previous research on the COFT (e.g. Graham, 1989a) has found that across individuals speed and accuracy tend to have a moderate to high positive correlation. This was again found in the current data as the correlations between the Percentage of Hits and Opening Time for the pretest, posttest, and NCOs were .60, .75, and .65 respectively. This is consistent with the results of all of the previous analyses. Some gunners either due to aptitude, experience, or both tended to be faster and more accurate while others tended to be slower and less accurate.

That speed and accuracy are correlated does not suggest which orientation is the best to employ when training. In an attempt to get a handle on the speed/accuracy tradeoff, an analysis was performed to determine whether a speed or accuracy bias was related to relative performance on the pretest, posttest, or NCOs. It is possible, for example, that the best EIA soldiers on the posttest might lean towards accuracy at the expense of speed, while the poorer soldiers did just the opposite.

To make the comparison, the Percent Hit Rates and Opening Times were converted to z-scores; this resulted in two distributions with equal means (0) and standard deviations (1.0.) The standardized Hit Rates were then added to the standardized Opening Times. Faster Opening Times, i.e., fewer seconds, were below the mean which meant their standardized values were negative. A positive sum indicated that relative to the other soldiers in the test the gunner was more accurate than fast. Conversely, a negative sum indicates that the gunner was relatively faster than he was accurate.

The analysis of speed/accuracy predominance found no significant differences between the high, middle, and low gunners on the pretest or the posttest nor between the high and low NCOs. On the pretest, the high performers were non-significantly biased in the direction of accuracy. On the posttest and with the NCOs the high performers were non-significantly biased toward speed. While these analyses did not find significant differences, analyses of speed/accuracy predominance may yield fruitful results in the future.

Discussion

The purpose of the research was to develop, validate, and refine a set of analytical methods for identifying the skills required to engage tank gunnery targets quickly and accurately, as well as to identify those skills that are trained on the COFT. The results showed the methods were effective in identifying a variety of tank gunnery skills. Given the success of the methods in present research, it is likely that they can generalized for use with other training devices. As the skills are identified, along with their patterned rates of development on the various devices, the information can be used to enhance the evolving device-based training strategy. The end result will be a training strategy that can more efficiently link amount and type of simulation-based training to skill development and field performance.

The analytical methods developed included skill development profiles which plotted performance measures across a range of skill levels. Skill levels were defined by level of training and relative level of performance, e.g., low, middle, and high performers within each group. The skill levels were thought to represent a combination of gunnery aptitudes and the effects of training. Error analyses were also conducted to identify the causes of rounds missing targets with misses being attributed to either aiming, tracking, or procedural errors. Methods for rating tracking performance were demonstrated and the results showed that the tracking ratings strongly predicted the hit rate on both moving and stationary targets. Methods for identifying the relative speed/accuracy orientation or predominance of the gunners were also developed.

The skill development profiles showed that the skills needed to accurately engage stationary targets developed very quickly, with performance for all but the poorest gunners asymptoting during normal OSUT training. This finding was true for both short and long range stationary targets and replicates Schmitz' (1957) thirty year old data that showed errors on stationary targets were generally not due to gunners' aim. In contrast to the accuracy skills, the skills needed for speed continued to develop across the range of skill levels.

Taken together, the various analyses showed that tracking skills largely accounted for speed and accuracy on both stationary and moving targets. Tracking skills were shown to still be improving at the highest skill levels with tracking errors still being prevalent with the NCOs on the moving targets. The pattern of tracking errors across the skill levels systematically progressed from being largely erratic to tracking too slow to tracking too fast. Somewhat surprising was that a large percentage of the NCO tracking errors were from tracking too fast. Tracking too fast was possibly due to gunners being trained to come up from behind moving targets.

The best gunners, i.e., the high NCO performers, demonstrated nearly perfect tracking patterns. The analysis of the Fire Times, i.e., from when they lased until they fired, showed that the high NCOs were able to hold a steady track after the lase when the sight picture displaced and as a result were able to fire more quickly than the others. With the exception of the best gunners, the movement of the reticle adversely affected the gunners' track of the target. The pattern of errors was magnified on the evasive helicopter targets of which the NCOs hit on only 14% of the rounds fired. Even the best NCO gunners failed to drop the lead when the unfamiliar evasive targets stopped moving. Fire control improvements to the M1A2 tank are believed to improve speed and accuracy for firing at moving targets such as these. The azimuth stabilized mirror on the gunner's primary sight (GPS) will eliminate reticle movement and new ballistic solutions and gravity control will aid helicopter engagements.

The results indicate that moving targets are most difficult and thereby required the greatest gunnery skill. Given the relative ease of training stationary target accuracy and that the same tracking skills seem to underlie killing both stationary and moving targets, more emphasis might be placed on training moving targets. Similarly, tank gunnery tests designed to assess gunnery skill levels, e.g., Tank Tables VIII and XII, would be better if they contained a majority of moving targets. It could be argued that Tank Table VIII and XII do not contain enough moving targets to be efficient. The analysis of the Engagement Times for the second target in the multiple engagements also proved to be a big performance discriminator. This suggests that multiple target arrays containing more than two targets may be even better discriminators. Also, considering that the results show that accuracy on stationary targets asymptotes very early, the requirement to progress half way through the I-COFT matrix before training on moving targets may not be most efficient. The advanced U-COFT training matrix currently under development will, however, train normal mode moving targets much earlier in the training schedule.

It is important to again note that the skills analysis in the present research only included main gun engagements fired in normal mode from a stationary tank. To determine the full range of gunnery skills and similarly to determine the test conditions which would likely yield the greatest discrimination of performance, one must also consider degraded mode conditions, machine gun engagements, and offensive engagements. Surprisingly, Campshure & Drucker (1990) and Hughes et. al.(1987) found higher correlations between amount of COFT training and performance on Tank Table VIII offensive engagements than between amount of COFT training and performance on Tank Table VIII defensive engagements. The reason for this relationship is not clear.

The error analyses showed systematic error patterns across skill levels, as well as individual patterns of errors. For stationary targets, the error analyses showed that the vast majority of misses were due to aiming high or low, as opposed to right or left. By being more aware of error tendencies, trainers could better help gunners avoid standard error patterns. For example, the gunner could be trained to devote extra attention to avoiding high/low aiming errors on stationary targets. Also, if a soldier were to repeatedly make a particular type of error, e.g., dropping the lead before firing at moving targets, the I/O should focus the feedback on that problem. The performance feedback presented in the COFT printouts tend to be evaluative rather than for the purpose of identifying individual performance deficiencies.

The COFT is best conceived of as a training tool that is used by trainers, namely the COFT I/Os. The quality of the COFT training is therefore directly determined by the quality of the feedback given by the I/O. As training technology continues to develop, it may be possible to aid the I/O by building an "expert training system" into the COFT. The expert system software would analyze performance, e.g., tracking rate, look for error patterns, e.g., that the gunner consistently tracked too fast, and make recommendations on how to improve specific facets of performance. For a more complete description of typical COFT error patterns and of particular training approaches used by I/Os, refer to Graham (in preparation).

Several types of errors were conspicuously absent in this research. There was virtually no ambushing of moving targets. Also, rapid slewing from the first to second target in a multiple target array did not cause excessive lead errors. The error analyses did, however, reveal a surprisingly high number of bad lases. The results also showed that while a variety of procedural errors occurred early, there were virtually no procedural errors by the end of the EIA I-COFT training.

Finally, the analysis of overall hit rate showed that following the 14 hours of EIA I-COFT training, the upper 2/3s of the EIA soldiers had hit rates equivalent to the lower half of the NCO gunnery instructors. It is important to note that the 14 hours of EIA I-COFT condensed into a one week period was probably the most intensive COFT training the soldier will receive in his enlisted career. The results nevertheless suggest that soldiers with high gunnery aptitudes can be quickly trained up to high levels of normal mode gunnery performance, if quality training is available.

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APPENDIX A

MEANS AND STANDARD DEVIATIONS FOR EIA HIGH/MIDDLE/LOW SPLIT AND NCO I-COFT AND U-COFT

EIA - All Targets Combined	PRE				POST			
	Low	Med	High	F	Low	Med	High	F
Percent Total Hits	.61 (.07)	.75 (.07)	.91 (.07)	28.35***	.85 (.03)	.93 (.02)	.98 (.03)	26.50***
Percent First Round Hits	.55 (.09)	.67 (.06)	.82 (.07)	19.94***	.82 (.05)	.88 (.06)	.91 (.04)	3.81*
Azimuth Errors	1.17 (.37)	1.07 (.21)	.77 (.21)	3.38	.80 (.14)	.59 (.07)	.51 (.13)	10.22***
Elevation Errors	.71 (.28)	.61 (.26)	.36 (.04)	3.65*	.28 (.05)	.27 (.04)	.25 (.03)	.56
Acquisition Time	10.66 (1.36)	9.58 (1.24)	8.94 (.63)	3.58*	8.78 (.81)	8.07 (.19)	7.80 (.86)	3.26
Lase Time	3.94 (1.01)	3.13 (.66)	2.96 (.78)	2.43	3.07 (.99)	2.19 (.49)	2.05 (.75)	3.09
Fire Time	1.77 (.54)	1.81 (.32)	1.86 (.25)	.08	1.69 (.34)	1.84 (.49)	1.59 (.30)	.60
Opening Time	16.37 (1.32)	14.52 (1.21)	13.76 (1.14)	7.20**	13.85 (.62)	12.36 (.29)	11.67 (.45)	33.00***

EIA- Single Stationary Targets	PRE				POST			
	Low	Med	High	F	Low	Med	High	F
Percent Total Hits	.88 (.08)	.96 (.06)	1.00 (.00)	7.00**	1.00 (.00)	1.00 (.00)	1.00 (.00)	na
Percent First Round Hits	.71 (.10)	.92 (.10)	.94 (.07)	11.33***	.98 (.05)	.96 (.10)	.98 (.05)	.17
Azimuth Errors	.40 (.13)	.31 (.11)	.30 (.06)	1.53	.27 (.05)	.26 (.05)	.25 (.08)	.17
Elevation Errors	.58 (.29)	.27 (.08)	.26 (.09)	6.30**	.25 (.06)	.22 (.03)	.21 (.04)	1.38
Acquisition Time	10.67 (1.74)	9.74 (1.89)	8.87 (1.10)	1.86	8.31 (.57)	8.27 (.40)	7.87 (.69)	.36
Lase Time	4.61 (1.85)	2.86 (1.03)	3.59 (1.14)	2.41	3.10 (.90)	2.29 (.45)	2.30 (1.00)	1.96
Fire Time	1.49 (.65)	1.40 (.40)	1.94 (.41)	2.01	1.59 (.32)	1.24 (.32)	1.36 (.37)	1.61
Opening Time	15.28 (3.02)	15.49 (1.70)	14.40 (2.13)	.36	12.51 (1.02)	11.82 (.96)	12.00 (.72)	.93

<u>Note.</u> Standard deviations are in parentheses.

* $p < .05$
** $p < .01$
*** $p < .001$

EIA- Multiple Stationary Targets

	PRE				POST			
	Low	Med	High	F	Low	Med	High	F
Percent Total Hits	.77 (.15)	.75 (.15)	.95 (.08)	4.21*	.95 (.08)	.98 (.04)	.98 (.04)	.65
Percent First Round Hits	.73 (.19)	.73 (.14)	.95 (.08)	4.67*	.95 (.08)	.98 (.04)	.98 (.04)	.65
Azimuth Errors	.69 (.15)	.74 (.30)	.46 (.19)	2.71	.32 (.03)	.35 (.09)	.33 (.15)	.15
Elevation Errors	.65 (.16)	.69 (.27)	.37 (.11)	4.98*	.35 (.07)	.32 (.03)	.26 (.07)	3.32
Acquisition Time	11.20 (2.10)	9.65 (2.50)	8.98 (1.17)	1.94	9.15 (2.01)	7.66 (1.04)	7.38 (.79)	2.82
Lase Time	2.41 (.75)	2.27 (.51)	1.98 (.30)	.94	2.18 (.73)	1.47 (.26)	1.60 (.80)	2.05
Fire Time	1.23 (.39)	1.57 (.36)	1.31 (.24)	1.70	1.23 (.16)	1.26 (.40)	1.08 (.21)	.72
Opening Time 1	13.52 (2.60)	14.39 (2.68)	12.68 (1.15)	.86	12.58 (1.99)	11.27 (1.35)	11.60 (1.66)	.99
Opening Time 2	30.92 (2.99)	31.56 (3.16)	31.90 (2.17)	.19	28.86 (1.46)	28.16 (2.54)	26.64 (3.07)	1.29

EIA- Single Moving Targets

	Low	Med	High	F	Low	Med	High	F
Percent Total Hits	.22 (.16)	.48 (.09)	.83 (.06)	46.24***	.63 (.12)	.83 (.12)	.89 (.10)	9.16**
Percent First Round Hits	.15 (.15)	.41 (.06)	.59 (.11)	22.71***	.46 (.05)	.69 (.05)	.83 (.06)	80.00***
Azimuth Errors	2.41 (1.06)	2.07 (.43)	1.51 (.44)	2.47	1.84 (.36)	1.08 (.25)	1.02 (.28)	14.21***
Elevation Errors	1.00 (.64)	.60 (.29)	.35 (.13)	3.72*	.28 (.09)	.24 (.06)	.26 (.05)	.63
Acquisition Time	10.11 (1.24)	9.37 (.99)	8.98 (.27)	2.31	8.89 (.76)	8.27 (.56)	8.14 (1.47)	.94
Lase Time	4.81 (2.07)	4.25 (1.75)	3.30 (1.18)	1.21	3.93 (1.51)	2.81 (.92)	2.26 (.73)	3.59*
Fire Time	2.58 (1.10)	2.47 (.54)	2.33 (.71)	.14	2.25 (.67)	3.00 (1.09)	2.33 (.52)	1.59
Opening Time	17.51 (2.12)	15.65 (1.32)	15.02 (.97)	4.18*	14.90 (.69)	13.88 (1.67)	13.10 (.63)	3.99*

Note. Standard deviations are in parentheses.

* $p < .05$
** $p < .01$
*** $p < .001$

NCO- All Targets Combined

	I-COFT			U-COFT		
	Low	High	t	Low	High	t
Percent Total Hits	.96 (.01)	.99 (.02)	4.01**	.97 (.03)	1.00 (.00)	na
Percent First Round Hits	.86 (.06)	.94 (.04)	2.50*	.87 (.05)	.95 (.06)	2.33*
Azimuth Errors	.54 (.06)	.39 (.07)	-3.68**	.59 (.16)	.48 (.09)	-1.33
Elevation Errors	.34 (.11)	.25 (.04)	-1.74	.31 (.04)	.29 (.04)	-.96
Acquisition Time	8.70 (.60)	7.47 (.44)	-3.69**	10.16 (1.22)	8.03 (1.23)	-2.75*
Lase Time	1.63 (.38)	1.35 (.29)	-1.31	1.73 (.44)	1.34 (.23)	-1.76
Fire Time	1.72 (.17)	1.51 (.12)	-2.29*	1.61 (.27)	1.29 (.36)	-1.57
Opening Time	12.11 (.92)	10.31 (.28)	-4.20**	13.49 (1.39)	10.66 (1.38)	-3.24**

NCO - Single Stationary Targets

	I-COFT Low	I-COFT High	t	U-COFT Low	U-COFT High	t
Percent Total Hits	.98 (.06)	.98 (.06)	.00	.98 (.06)	1.00 (.00)	na
Percent First Round Hits	.93 (.11)	.95 (.11)	.35	.90 (.11)	.98 (.06)	1.41
Azimuth Errors	.31 (.05)	.20 (.07)	-2.82*	.27 (.08)	.30 (.05)	.72
Elevation Errors	.33 (.15)	.20 (.05)	-1.82	.24 (.02)	.28 (.06)	1.15
Acquisition Time	8.63 (1.05)	7.05 (.66)	-2.86*	10.77 (1.09)	8.01 (1.53)	-3.28**
Lase Time	1.97 (1.27)	1.31 (.39)	-1.11	1.82 (.78)	1.48 (.52)	-.83
Fire Time	1.32 (.30)	1.32 (.32)	.01	1.44 (.23)	1.04 (.47)	-1.69
Opening Time	11.92 (1.86)	9.68 (.51)	-2.61*	14.03 (1.42)	10.53 (1.79)	-3.43**

Note. Standard deviations are in parentheses.

* $p < .05$
** $p < .01$
*** $p < .001$

NCO- Multiple Stationary Targets		I-COFT			U-COFT	
	Low	High	t	Low	High	t
Percent Total Hits	.98 (.05)	1.00 (.00)	na	1.00 (.00)	1.00 (.00)	na
Percent First Round Hits	.98 (.05)	.98 (.05)	.00	.96 (.06)	.98 (.05)	.63
Azimuth Errors	.35 (.07)	.30 (.06)	-1.14	.43 (.15)	.41 (.10)	-.23
Elevation Errors	.34 (.14)	.33 (.05)	-.22	.40 (.12)	.34 (.02)	-1.07
Acquisition Time	8.55 (.56)	7.68 (.90)	-1.86	9.54 (1.84)	7.39 (1.42)	-2.06
Lase Time	1.30 (.20)	1.01 (.21)	-2.18	1.12 (.46)	.61 (.14)	-2.37
Fire Time	1.31 (.43)	1.29 (.48)	-.07	.92 (.19)	.81 (.31)	-.71
Opening Time 1	11.16 (.75)	9.98 (.37)	-3.18*	11.58 (2.12)	8.81 (1.64)	-2.31*
Opening Time 2	27.27 (1.88)	21.81 (2.48)	-3.93**	19.36 (2.48)	16.03 (3.06)	-1.89
NCO - Single Moving Target						
Percent Total Hits	.93 (.06)	1.00 (.00)	na	.94 (.08)	1.00 (.00)	na
Percent First Round Hits	.71 (.13)	.91 (.09)	2.85*	.74 (.12)	.89 (.12)	1.89
Azimuth Errors	1.02 (.25)	.66 (.27)	-2.18	1.06 (.39)	.73 (.22)	-1.67
Elevation Errors	.33 (.18)	.22 (.03)	-1.36	.30 (.08)	.26 (.07)	-.89
Acquisition Time	8.90 (.37)	7.68 (.42)	-4.89***	10.17 (1.36)	8.68 (1.04)	-1.93
Lase Time	1.61 (.65)	1.72 (.47)	.29	2.26 (.67)	1.94 (.67)	-.75
Fire Time	2.53 (.34)	1.91 (.16)	-3.73**	2.46 (.69)	2.02 (.64)	-1.05
Opening Time	13.04 (.97)	11.30 (.40)	-3.70**	14.88 (1.75)	12.63 (1.00)	-2.49*

Note. Standard deviations are in parentheses.

* $p < .05$
** $p < .01$
*** $p < .001$